ehp ENVIRONMENTAL HEALTH PERSPECTIVES

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RESCUING WATER FROM THE ROOF

Students read the *EHP* news article **Paving Paradise: The Peril of Impervious Surfaces**, and identify problems with paved surfaces and their associated health concerns. They calculate the volume of water that could be collected from the school roof and discuss ways to reuse the water.

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Overview

Grade Level: **9–12**

Subjects Addressed: General Science, Environmental Science, Mathematics, Geometry, Health

Class Time: Part 1 only: **45–50 minutes;** Parts 1 and 2: **2 hours**.

Each student should begin by reading **Paving Paradise: The Peril of Impervious Surfaces** http://ehponline.org/article/info:doi/10.1289/ehp.113-a456

OBJECTIVE

By the end of this lesson students should be able to **identify** environmental health concerns related to paved surfaces; **calculate** the area of a roof surface; **perform** unit conversions between inches, centimeters, and meters, and between cubic meters and gallons; and **calculate** a volume of water.

MATERIALS (per student)

- 1 copy of the article **Paving Paradise: The Peril of Impervious Surfaces**
- 1 copy of the Student Instructions and the Water Rescue Data sheet if the student will be doing Part 2
- Calculator

MATERIALS (per group)

- Large tape measure with meter units for each student group

VOCABULARY WORDS

Aquifer, Area, Asphalt, Green roof, Heat island, Impervious, Perimeter, Porous, Volume

Aligning with Standards

NATIONAL SCIENCE EDUCATION STANDARDS

Specific Content Standards

Unifying Concepts and Processes Standard

- Change, constancy, and measurement

Science As Inquiry Standard

- Abilities necessary to do scientific inquiry

Life Science Standards

- Interdependence of organisms

Science and Technology Standards

- Abilities of technical design
- Understanding about science and technology

Science in Personal and Social Perspectives Standard

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Skills Used or Developed

- Communication (notetaking, oral, and written)
- Comprehension (listening, and reading)
- Computation
- Critical thinking and response
- Graph reading
- Observation
- Technological design
- Unit conversions

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Background Information

The article provides sufficient information to complete Part 1 of the lesson. The health effects information that students provide in their answers can be general (i.e., a chemical is a carcinogen or toxic) or inferred (i.e., heat can cause heat stroke or flooding can cause drowning or automobile accidents), because the article provides only a few specific examples of health effects.

Part 2 of the lesson requires students to measure the perimeter of the particular school building to be studied, calculate the area of the roof, and then calculate the volume of water that comes off the roof.

If the shape of the school building is square or rectangular, then most students should be able to do all of the calculations needed to estimate the volume of water. If the building has a complex or unusual shape, you may want to have less-advanced students treat the building as a square or rectangle and more-advanced students, or those who have taken geometry, attempt to calculate the actual area using their perimeter measurements.

- The formulas for calculating the area of shapes are:
- Square or rectangle: length x width = l x w
- Triangle: 1/2 base x height = 1/2b x h
- Circle: p x radius squared = πr^2
- Trapezoid: 1/2 (short side + long side) height = 1/2 (a+b) h
- Ellipse: π (short radius x long radius) = πab
- Sector: 1/2 r^2 (angle in radians) = 1/2 $r^2\theta$

Students will also be asked to perform unit conversions. A website for unit conversions is included in the Resources section to assist you with grading. When students perform their calculations they should show all of their work or steps clearly, including the cancellation of their units. They should also have the correct units displayed at the end of their calculations. Students at all levels should do this because it demonstrates to you that they understand the calculations, and more importantly, it prepares them for the more advanced and complex calculations and unit conversions used in physics and chemistry.

NOTES AND HELPFUL HINTS

- In this activity we are assuming that all of the water that falls onto the roof could be collected. In reality some of the water may evaporate, exit from multiple areas, or pool on the roof.
- If the roof of the school is sloped and without eaves, then the amount of water collected would be similar to that of a flat roof. However if the roof has large overhangs then the amount of water collected could be significantly more.
- Students could design a water collection, storage, and distribution system for the school. They should consider possibilities like using pumps or gravity feeds to distribute the water.
- Students could also calculate the potential cost savings in water bills for the school if stored rainwater were used to water landscaping.
- If the school purchases some rain barrels be sure there is netting or covers to prevent mosquitoes from reproducing in standing water. You may want to have students investigate or discuss the potential concerns with mosquitoes as vectors for diseases.
- If you have access to water quality testing kits, you may want to have students collect and test water from the roof and parking lots. Be sure to have students wear protective gear when collecting and testing the water.

Prepping the Lesson

- Download the article **Paving Paradise: The Peril of Impervious Surfaces** at **http://ehponline.org/article/info:doi/10.1289/ehp.113-a456**.
- Make copies of the Student Instructions.
- Review the article, lesson, and Student Instructions.
- Decide if you want students to do both parts of the lesson.
- If students do Part 2, gather the necessary materials.
- Depending on the layout of your school and the level of your students, be prepared to review geometry concepts as needed to assist them with calculating the area of the roof and the volume of rain captured by the roof.

Implementing the Lesson

1. Hand out the Student Instructions and a copy of the article **Paving Paradise: The Peril of Impervious Surfaces**.
2. Instruct the students to read the article and answer the questions in Part 1 of the Student Instructions.
3. If the students will be doing Part 2 of the lesson, inform them that they are going to measure the outside (perimeter) of the building and then will use those measurements to calculate the area of the roof and the volume of water that comes off the roof during a rainstorm.
4. Review basic geometry concepts as needed and instruct the students about how and where they will measure the school (i.e., just the main building, the entire complex, just square and rectangular parts, etc.). If the school has several buildings you may want to assign buildings to groups.
5. Break the students into groups and give them a tape measure and data sheet. Remind them to collect the data in meters.
6. After the students have collected the measurements, instruct them to individually do the calculations. Each student will turn in his or her own work. Remind the students to show their work and the units.
7. After the students have calculated the number of gallons of water that come off the roof, discuss some of the possible uses or applications of that water (e.g., use it to water lawns or gardens). You may also want to discuss some of the limitations of using rain barrels, especially if you live in a wet climate.

   Have students generate ideas about how more water could be stored and used throughout the year (e.g., use large underground cisterns).

Assessing the Lesson

Part 1

Step 2:

Answer the following questions:

a) Look at the graph titled "Impervious Cover of Various Land Uses" on page A458. What percentage of land is covered by the impervious roof surface for a common industrial complex?

Approximately 24%

b) List three examples of problems caused by impervious surfaces.

Students may have any three of the following examples. If a student lists an example that is not here, check for accuracy.

- They collect particulate matter, nitrogen oxides from car exhaust, rubber particles, metals from brakes and building materials, phosphates from fertilizers, bacterial contamination, antifreeze, petroleum products, chromated copper arsenate, creosote, and pentachlorophenol from wood products; asphalt itself contains polycyclic aromatic hydrocarbons.
- Water moves too quickly, causes erosion, and cannot be absorbed into the ground.
- Causes turbidity and overfertilization in lakes and streams, which may cause algal blooms.
- Flash flooding on roads, overfilling sewage systems.
- Acts as a "heat island."

c) Give three examples of how large amount of impervious surfaces may adversely affect human health.

- Students may have any three of the following examples. If a student lists an example that is not here, check for accuracy.
- Toxic and carcinogenic chemicals can run off into the drinking water supply and lakes and streams where people may eat the fish or swim.
- Lack of infiltration into the groundwater can significantly reduce the drinking water supply in some areas.
- Bacteria from animal fecal matter or overflowing sewage systems can cause illness.
- Increased heat can cause heat exhaustion or heat stroke in people, especially the elderly.
- Flooding can cause drowning or automobile crashes.

d) Provide examples of how porous pavements and green roofs help solve identified problems.

- A complete answer would list all of the examples below. Assign points based on the completeness of the answer.
- Porous pavements can increase traction and visibility on a wet road.

- Some pollutants can be broken down into less-harmful substances by microbes just below the surface of porous pavements or in the soil layer on the green roofing material.
- Porous pavements and green roofs slow the speed of the water.
- Green roofs can decrease the roof temperature.

Part 2

Step 3:

Each student should have completed the Water Data Sheet and have a calculated area for the building they measured. Look for details in their notes/descriptions (i.e., can you tell exactly which wall they measured?).

Also check for accuracy in their area calculations and use of units, and that they showed all of their work.

Step 4:

Fill in the Water Conversion Table below to calculate the volume of water in cubic meters and gallons that could be collected from the roof during two different rainstorms. Unless your teacher instructs otherwise, assume the roof of your school is flat. Show your work on a separate sheet of paper and clearly show unit cancellations. Unit conversions are listed below.

- **Volume = the number of cubic units to fill a three-dimensional space**
- **1 cubic meter = 264.2 gallons [US, liquid]**
- **1 centimeter = 0.01 meter = 0.39 inch**

Volume answers will be unique to the school, but sample calculations are provided below. When students do unit conversions they should always show their calculations, unit cancellations, and ending units. This will develop good habits for more involved series unit conversions often encountered in physics and chemistry and will help them understand the mathematical process.

Water Conversion Table

	Rained 1"	Rained 2.7"
Convert inches to centimeters (cm)	1 ~~in~~ x 1 cm/0.39 ~~in~~ = 2.6 cm	2.7 ~~in~~ x 1 cm/0.39 ~~in~~ = 2.6 cm x 2.7 = 7.0 cm
Convert cm to meters (m)	2.6 ~~cm~~ x 0.01 m/1 ~~cm~~ = 0.026 m	7.0 ~~cm~~ x 0.01 m/1 ~~cm~~ = 0.07 m
Volume of rain off the roof (m^3)	Area (assuming a rectangular school building) = 30 m x 45 m = 1,350 m^2 Volume = area x height = 1,350 m^2 x 0.026 m = 35.1 m^3	Using the same area. Volume = 1,350 m^2 x 0.07 m = 94.5 m^3
Volume of rain gallons	35.1 ~~m^3~~ x 264.2 gallons/1 ~~m^3~~ = 9,273 gallons	94.5 ~~m^3~~ x 264.2 gallons/1 ~~m^3~~ = 24,967 gallons

Step 5:

If the average rain barrel holds 55 gallons, how many rain barrels would you need to collect all of the water from a storm that produces 1" of rain? Show your calculation below or on a separate piece of paper.

$$\frac{9{,}273 \text{ gallons}}{55 \text{ gallons/barrel}} = 168.6 \text{ barrels} \approx 169 \text{ barrels}$$

RESOURCES:

Environmental Health Perspectives, News by Topic page. Choose Water Pollution, Built Environment,
http://ehp03.niehs.nih.gov/article/browsenews.action

Math is Fun, Area of Plane Shapes,
http://www.mathsisfun.com/area.html

Online Conversions,
http://www.onlineconversion.com/

The Rain Water Harvetsing Community,
http;//www.harvesth2o.com

Water Muddle Up and Clean up, UNC Superfund Basic Research Program,
http://www.ie.unc.edu/erp/resources/Water_Muddle_Up_and_Clean_Up_Lesson.pdf